Ionospheric and Solar Plasmas in Geospace Storms

T E Moore, M-C Fok, D C Delcourt, J A Fedder, M W Liemohn, S P Slinker

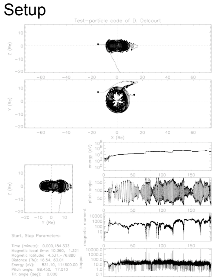
ABSTRACT

We consider the formation of ring current like plasmas in the inner magnetosphere under moderately active conditions that precondition the plasma sheet and ring current-like region for full fledged geospace storms. We seek to better understand recent IMAGE energetic neutral atom observations showing that proton injection is relatively smooth and continuous, whereas O+ injection is episodic in close association with substorms. We use a modeling framework of collisionless test particle motions in magnetospheric fields from the LFM magnetohydrodynamic simulation. The simulation is used to generate bulk properties and detailed velocity distributions at key locations, for comparison with observations. Particles are initiated in regions representative of the solar wind proton source upstream of the bow shock, the polar wind proton source, and the auroral zone enhanced outflows of O+, or auroral wind. We first consider steady growth phase conditions after 45 minutes of southward inteplanetary magnetic field, Bz = -5 nT (By=0). Solar wind protons enter the ring current region principally through the dawn low latitude boundary layer, while polar wind protons and auroral wind O+ enter the ring current region through the midnight central plasma sheet. We then consider dynamic conditions over a three hour period containing a substorm dipolarization produced by a reconnection event in the mid-tail plasma sheet, including a plasmoid ejection. Since solar wind and ionospheric plasmas take different transport paths they may be expected to respond differently to substorm dynamics of the magnetotail, as recently observed. Polar wind protons make a minor contribution to the ring current region pressure under steady conditions, but auroral wind O+ can dominate the preconditioning region pressure, when dayside outflow is strongly enhanced as it is observed to be during periods of enhanced solar wind dynamic pressure fluctuations.

- Inputs
  - Dayside oval emits 1e9 cm^{-2} s^{-1} O$^+$ at 0 - 10s eV
    - Hourly Δ(Pd) ~ 1 nPa per Moore et al., 1999.
  - Nightside oval emits 1e8 cm^{-2} s^{-1} O$^+$ at 0 - few keV
  - These fluxes could be much lower but would rarely be higher
  - Tend to be in this ratio except for Alfvenic aurora near the nightside polar cap boundary, which matches dayside flux
- Outputs
  - Peak density to 10 cm^{-3}, vs 1 cm^{-3} for polar wind or solar wind.
  - Peak pressure to 10s nPa, vs 1 for solar wind or <0.1 for polar wind
  - Dayside outflow contributions dominate density and pressure
  - NBz stops upstream escape over poles

Sample Trajectory Numerical Setup

- Delcourt [1993] full equations of motion w/ g
  - GC for r<3Re, randomized
- 4th order Runge-Kutta
- Time step 5° gyrophase
- Linearly interpolated MHD fields from LFM simulation
- Spherical MHD grid with axis along Xgsm.
  - Polar resolution 2°
  - Azim resolution 5.5°
  - Radius varies with r, Polar
- *Replaces* Volland-T89



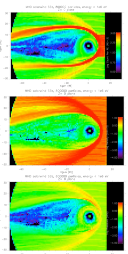
Computing Plasma Moments

- Each particle weighted by a source fluence F [sec^{-1}] of particles on each trajectory.
- Particle contributes to density in a bin according to:
  - dN = F * dt / V
    - dt = time in bin
    - V = volume of bin
- Pressure from weighted sum of particle energies
- Velocity moments from weighted sum of particle velocities

N

n

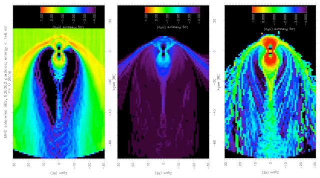
P



STATIC FIELDS

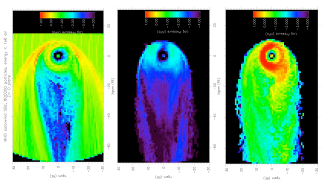
Solar, Polar, Auroral Wind - XZ

Pressure range: 1e-4 to 1e1 nPa

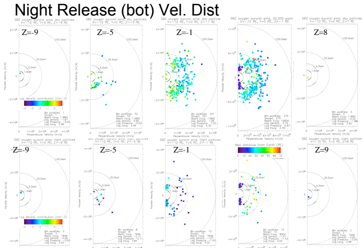


Solar, Polar, Auroral Wind - XY

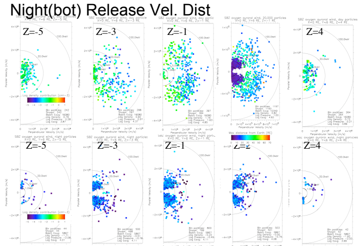
Pressure range: 1e-4 to 1e1 nPa



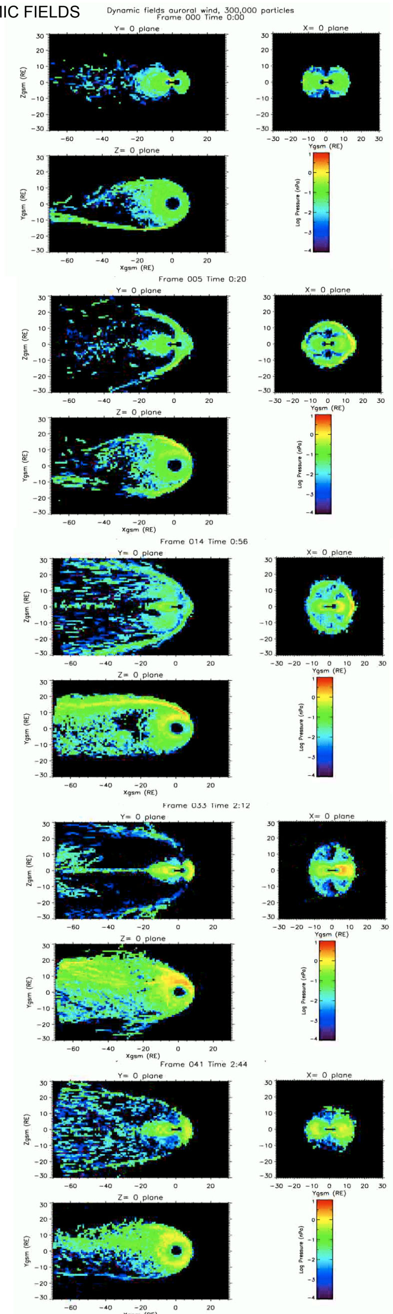
Day Release (top) Vel. Dist X,Y=-10,0
Night Release (bot) Vel. Dist



Day (top) Release Vel. Dist at X,Y= 0,6
Night(bot) Release Vel. Dist



DYNAMIC FIELDS



End of NBz

O+ accumulation within inner magnetosphere

Just after SBz

O+ jets over the poles and along flanks

Onset of reconnection

Polar cap cloud of released O+

Plasmoid released

Reconnection Continues

Cloud of released O+ forms very thin plasma sheet and enters dusk sector

NBz wave passes along magnetopause

Pressure inner magnetosphere goes symmetric

CONCLUSIONS

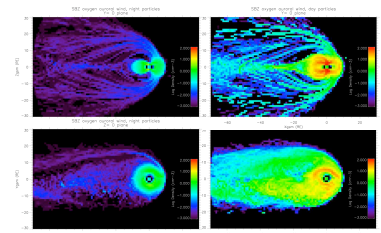
Solar wind protons transported via flank magnetopause, direct to inner plasma sheet and ring current-like region

Polar wind protons and auroral wind O+ transported to mid tail plasma sheet and thence into the inner magnetosphere

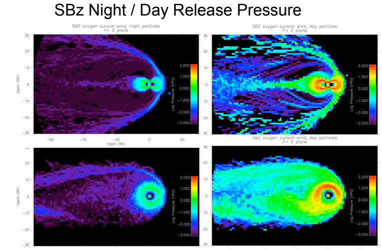
Auroral wind O+ gains the greatest pressure in the plasma sheet and inner magnetosphere, responds dramatically to substorm dipolarization

Trapping and accumulation, with release when convection picks up, may be as important for O+ as for H+, or more so.

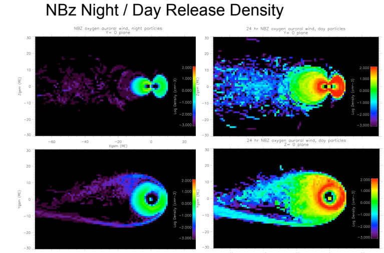
SBz Night / Day Release Density



SBz Night / Day Release Pressure



NBz Night / Day Release Density



NBz Night / Day Release Pressure